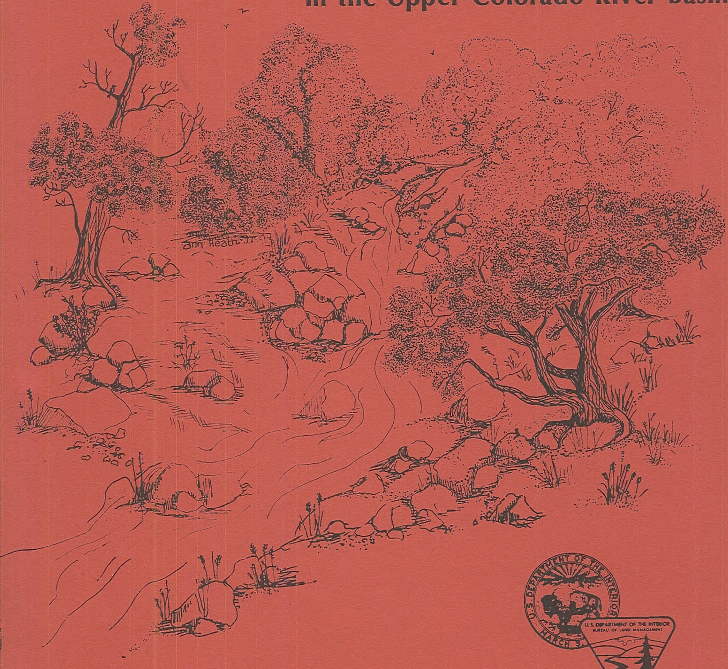
Control of SALINITY from Point Sources Yielding Groundwater Discharge and from Diffuse Surface Runoff in the Upper Colorado River Basin



1978-79 Status Report

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CONTROL OF SALINITY FROM POINT SOURCES YIELDING GROUNDWATER DISCHARGE AND FROM DIFFUSE SURFACE RUNOFF IN THE UPPER COLORADO RIVER BASIN

FY 1978-79 STATUS REPORT

February 1980

UNITED STATES DEPARTMENT OF THE INTERIOR
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The Bureau of Land Management has expanded its study of sources of salt yielded from public lands to include salinity from groundwater discharge. The Bureau has also continued to investigate the effects on salinity in surface runoff of grazing of livestock and other uses of the land having a potential to cause soil disturbance. Grazing by livestock can be an important means of controlling salinity in runoff, when grazing follows a schedule designed to provide systematic rest for vegetation and soils during critical periods. In some cases, removal of livestock or off-road vehicles may be required. Progress is being made toward developing technically feasible methods for controlling highly saline groundwater point discharges. Further study is needed and could be accomplished through demonstration projects. The cost-effectiveness of controlling saline groundwater is examined through several case studies.

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Bureau of Land Management

John C. Clark	Range Conservationist
Ronnie D. Clark	Watershed Specialist
Edward R. Frandsen	Range Economist
James L. Hancock	Range Conservationist
Richard A. Herbert	Hydrologist
Ronald L. Kuhlman	Soil Conservationist

Water and Power Resources Service

Michael B. Bessler	General Engineer
Robert I. Strand	General Engineer

Soil Conservation Service

Karl R. Klingelhofer	Soil Conservationist

State Governments

Myron B. Holburt	Chief Engineer, Colorado River Board of California
Ernest Weber	Staff Engineer, Colorado River Board of California
Carl L. Slingerland	Staff Engineer, Interstate Stream Commission of New Mexico

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I. INTRODUCTION

Since publication of the 1977 Salinity Status Report, investigations have continued concerning grazing by livestock and its effects on salinity. Research findings associated with effects of grazing on salinity, overlooked during the first years of the salinity study, have been reviewed. Findings published since the printing of the 1977 Salinity Status Report (3) have also been reviewed. Information pertinent to the salinity problem on public lands has been abstracted and included in this report. The 1977 report concluded that a reduction in salinity from rangelands could be achieved by adjusting the intensity and timing of grazing. Suggested options for grazing management for salinity control must be balanced by the decisionmaker with all other management purposes and objectives. Maximum livestock production, wildlife objectives, and a host of other multiple land use values must be considered in selecting a grazing management program. Properly designed grazing systems incorporating salinity control objectives can be effective in controlling salt concentrations in surface runoff.

Possible means of controlling salinity from diffuse surface and point source groundwater are examined in this report and presented as examples to aid in the evaluation of future projects.

This report addresses salinity originating in surface runoff and groundwater from the public lands. An earlier analysis determined that surface runoff from these lands yields approximately 8 percent of the total salt load of the Upper Colorado River Basin. This compares with 7 percent from lands administered by others, 38 percent from natural groundwater sources, 41 percent from irrigation return flow, and 1 percent from industrial and municipal sources. The remaining 5 percent were unaccounted for and are well within the limits of error for these calculations.

II. OBJECTIVES

A. General Goals of BLM Salinity Study:

1. To continue to investigate causes of salinity in surface runoff from public lands.

2. To investigate causes of salinity in groundwater.

3. To incorporate research findings into salinity control procedures.

4. To further test the validity of existing erosion control techniques for their ability to control salinity.

B. Specific Objectives:

1. To assess the salt contribution from groundwater throughout a vast area within the Upper Basin. This includes collection and analysis of data from key locations not previously investigated. Also to analyze these and existing data to obtain a more complete picture of the quantity and quality of groundwater. Finally, to relate groundwater data to geologic formations and other site conditions. This work was contracted to the Geological Survey (GS).

2. To investigate specific saline groundwater point discharges and to monitor quantity and quality of water and yearly variations.

3. To study the technical and economic feasibility of controlling point sources of saline groundwater discharge.

4. To develop specific control practices that will best reduce salinity in surface runoff.

III. INTERRELATIONSHIPS BETWEEN GRAZING MANAGEMENT, RANGELAND CONDITION, AND SALINITY

Since publication of the 1977 Salinity Status Report (3), investigations have continued concerning grazing by livestock and its effects on salinity. Conclusions reached in the 1977 report were:

- Disturbance and movement of saline soils, through increased storm runoff, will increase rangelands contribution to the salinity of perennial stream systems.

- Increases in the area of ground covered by live vegetation and surface litter (dead plant material), reduced compaction of the surface few inches of soil, and increased friability (soil tilth) of the soil surface will increase infiltration and reduce runoff, hence reduce saline water yield from saline lands.

Based on these assumptions, it was theorized that proper management of livestock grazing, with the intent of stabilizing saline soils, would reduce salinity. Further analysis and a continued search of published results of studies dealing with hydrologic responses to grazing are outlined in the following sections.

Unregulated grazing by herbivores (domestic, feral, and wildlife) is considered to be a significant factor in causing increases of salinity in overland or surface runoff from saline wildlands. Grazing, especially by domestic livestock, is the most extensive use of these federally, state, and privately controlled lands. Meehan and Platts (32) state that rangeland management is closely interrelated with water management, observing that "the combined effects of geology, climate, geomorphology, soil, vegetation, and water runoff often result in unstable stream conditions in the natural state. When land uses place additional stress on aquatic habitats, damage usually occurs." Water management and maintenance of stable stream channels, therefore, are closely interrelated to control of salinity from surface runoff on rangelands.

The BLM administers about 150 million acres of grazing lands in the western United States (10, 25). Of these, 135 million acres are producing livestock forage below their potential. The Comptroller General reported that allotment management plans, outlining systematic grazing schedules, did not exist for 107 million acres of public lands (10). Land deterioration was principally attributed to "poorly managed livestock grazing." The report cited a 1976 address by the BLM Director to a group of Nevada public land users, in which he stated that unauthorized grazing by numbers of livestock in excess of those allowed by BLM "was the largest contributor to the state's deteriorated rangelands."

It is true, however, that giant strides have been made in improving range conditions over the years since the Taylor Grazing Act was passed in

1934. Before 1934, rangelands were grazed indiscriminately by large herds of cattle, sheep, and horses. The BLM has reduced livestock numbers to the level of forage produced and designated ranges for use during the proper season. Grazing management systems designed to protect the basic soil and vegetation resource have been implemented in some areas where funding and manpower have been provided.

The Council for Agricultural Science and Technology (14) reports that the degree to which grazing enhances other resources depends on the kind of range, objectives of grazing management, and skill of range managers. In order to be effective, "grazing must be scientifically controlled and responsive to the needs of all users." Proper management of all kinds of grazing animals can be an effective salinity control practice. This management may include intensive grazing management programs or, in some cases, temporary or total exclusion of livestock (2, 16, 18, 19, 32, 40). Adjustments in timing of grazing or numbers of animals may continue to be necessary in the future in order to protect the resources. However, adjusting livestock numbers alone is not the answer; grazing management systems which meet the goals of the land use plan are also needed (25).

The following are important factors which relate to the success of any grazing management system devised to reduce salt concentrations in surface runoff from rangelands:

A. Intensity of Grazing

The intensity of grazing can affect factors which cause increases in salinity. In an extensive review of the literature, Gifford and Hawkins (17) found that grazing influences infiltration. They note that it is "difficult to differentiate between the influences of moderate and light grazing," but that there "is a distinct impact from heavy grazing which is statistically different from that of light/moderate." Rauzi and Hanson (35) found a nearly linear relationship existed between increasing grazing intensity and decreasing rate of water intake. Knoll and Hopkins (23), Rauzi (33), and Rhoades et al. (37) found significant differences in infiltration rates between nongrazed and lightly or moderately grazed areas. Smeins (38) and Johnson (20) both state that grazing management practices designed to increase livestock production also have a definite impact on the interrelationships of soil, vegetation, and hydrologic processes. The degree of influence upon hydrologic responses is related to intensity of grazing, and the harmful effects of grazing are greatly reduced by light and moderate grazing.

Rauzi and Hanson (35) found a significant relationship between species composition of grasses and grazing intensity. This work was later supported by Hanson et al. (18). Heavy and moderate grazing resulted in a deterioration of vegetation from midgrasses to short grasses and sedges. Measurements recorded 97 and 80 percent composition of blue grama and buffalograss (short grasses) on the heavy and moderate grazing areas, respectively. Midgrasses (predominantly western wheatgrass) were maintained on the lightly grazed area.

Johnston (21), Rauzi (33), and Rhoades et al. (37) found significant differences in water intake rates on areas grazed at rates between light, moderate, and heavy intensity for periods of more than 20 years. Hanson et al. (18) found that after 26 years areas grazed heavily yielded significantly more runoff than those grazed moderately, and moderate grazing yielded significantly more runoff than from areas grazed only lightly. McCarty and Mazurak (29) reported significant increases in soil bulk density and decreases in total soil porosity on areas grazed at heavy-continuous and moderate-deferred-rotation rates over nongrazed areas after 25 years of treatment.

B. Timing of Grazing or Rest Periods

Martin (28) reported on data believed to support "the view that little benefit is gained by resting the range for only part of a normal grazing period." It was suggested that a grazing schedule for semi-desert ranges in Arizona should provide rest during 2 out of 3 years when plants are growing. It was also stated that a grazing system should be designed to remove 40 percent of the perennial grass production. Smeins (38) believes that periodic, short term, and partial defoliation of plants may have beneficial effects on hydrologic processes as well as on vegetation. It was stated that a favorable forage resource may be maintained, erosion hazard not increased, and good quality runoff water possibly increased.

Lusby (26) reported on data collected during two distinct study periods at Badger Wash, Colorado. In the first period (1953-65), heavy grazing by sheep and cattle occurred during the winter and spring (November 15 to May 15). Grazing by sheep in the second period (1966-73) was at a moderate level during the winter (November 15 to February 15). Rate of runoff and sediment loss were used as indicators of site stability. Sediment loss during the winter-sheep grazing was 29 percent less than that during the sheep-cattle winter-spring grazing and was somewhat less than that in areas completely removed from grazing for at least 20 years. The report concludes that moderate grazing during winter is not significantly more harmful than nongrazing. Heavy grazing (greater than 60 percent utilization) and grazing during spring when soil is moist are definitely detrimental. Discussion with Lusby (27) revealed that overall, moderate winter grazing produced 10 percent more sediment loss than nongrazing.

C. Range Condition (Plant Vigor, Density of Vegetal Ground Cover, Litter, Soil Tilth)

Rauzi et al. (34) conducted water studies for several years on rangelands in the mixed-grass and tall-grass prairies in six Northern and Central Plains States. It was found that both live vegetation and litter were highly correlated with water intake rate. Soil structure was the most important soil influence on infiltration and was second in general importance after vegetation. It was stated that range condition is directly related to water intake. Good condition ranges had a higher herbage production, greater mulch material (litter), and a more crumbly or granular surface structure conducive to a high rate of water intake.

Rauzi and Zingg (36) compared water intake data from many sites over seven Great Plains States, representing a variety of soils and climate. Water intake was significantly greater on ranges in good condition than on those in poor condition, irrespective of soil texture. McGinty et al. (30) found no significant differences in infiltration rate between a 4-pasture grazing system and a long-time enclosure, both presumably in good condition.

Buwai and Trlica (8) and Trlica et al. (39) conducted defoliation studies on a semiarid northwestern Colorado rangeland. These data indicate the effects of defoliation on plant health depend upon the species of plant, stage of growth (phenology), and number of defoliations. A number of plant species produced smaller herbage yields and showed reduced vigor following multiple defoliations at a moderate level. They were most severely affected by heavy defoliations. A number of plant species recovered within 14 to 26 months after a single heavy defoliation. Plants clipped when green or during the rapid growth stage did not make complete recovery following the rest period. Cook and Childs (12) state that plant vigor may have also been affected by the harsh conditions of the desert site. The implication is that desert ranges in the Intermountain area are in a delicate natural balance and can deteriorate rapidly if not used correctly.

Laycock (24), using species composition and plant vigor as indices of change, found desert ranges in poor condition improved when grazed only in the fall, while those in good condition deteriorated under spring grazing. Cook (11) found 60 percent utilization of cold desert plants during winter was too severe to maintain plants in good vigor. The rate of recovery of plants from defoliation was also proportional to the initial state of plant vigor. Plants grazed when in low vigor were slower to recover under complete rest. It was suggested that 50 percent utilization would maintain optimum vigor and sustained yield.

Costello and Turner (13), during a study of more than 100 exclosures, found that recovery of perennial vegetation (especially shrubs) from effects of grazing was very slow under natural conditions. Exclosures over 30 years old showed the greatest percentages of the highly palatable plants. Willard and Herman (42) report that improvement in range condition is slow on the Northern Great Plains, even under grazing management. This was true for grazing systems that did not allow at least one full year of rest for pastures during the grazing cycle. Greater improvement in soil and plant conditions was observed from winter grazing than from rest-rotation. This was attributed to frozen soils, reducing the effect of livestock trampling on soil compaction.

IV. CONTROL OF SALINITY IN SURFACE RUNOFF

Salinity in surface runoff is believed to be directly related to content and availability of salt in soils and movement of soils by erosion. Therefore, salinity should be reduced through any activity which leads to increased infiltration and reduced or controlled runoff. The major causes of soil disturbance and salinity on public lands are grazing by domestic livestock, feral horses and burros, and wildlife; recreation activities, including off-road vehicles (ORV); oil-gas and mineral exploration; mining claim assessment work; and development activities and final production of oil-gas wells, underground mines, and surface mining of coal resources.

A. Oil-Gas Activities, Mining, and ORV

Control of salinity requires that uses by man be allowed only to the degree that they do not result in loss of soil. In the case of surface mining, where the soil and vegetation are completely destroyed and highly saline or other toxic minerals are brought from great depths to the surface, mitigating measures will be needed. These should include retention dams to collect and hold toxic runoff, proper design of support facilities, such as access or haul roads, and restoration of topsoil and vegetation to the site when mining operations are completed. When ORV use is allowed on saline, fragile soils, it should be recognized that it may cause irreversible harm to soils and vegetation. Control of salinity can be accomplished by confining ORV use to prescribed areas where runoff and sediment can be retained in reservoirs.

B. Grazing Management

For purposes of this report, the following definitions are used for grazing intensities: light, 21-40 percent utilization; moderate, 41-60 percent utilization; and heavy, 61-80 percent utilization of the usable vegetation; see BLM Manual on Range Studies (1).

Effects of extensive use, such as livestock grazing, on salinity can be reduced through proper application of accepted grazing management principles. These include the allowance of grazing when soils and plants are least harmed by trampling or defoliation (proper season of use), control of livestock numbers to reduce harmful impacts, rotation of grazing and rest treatments to increase vegetative cover, and total exclusion of grazing where necessary. Key elements to be considered when prescribing grazing treatments are soil and vegetation factors as they relate to reduction of salt concentration in surface runoff. Treatments prescribed may be different from those designed when maximization of livestock benefits is appropriate.

BLM (3) described general characteristics of grazing treatments that could be prescribed for three classes of saline lands, i.e., nonsaline-slightly saline, moderately saline, and highly saline. No changes are suggested for treatments applied to nonsaline-slightly saline and moderately saline lands.

To reiterate:

1. Nonsaline-Slightly Saline Lands

The objective of grazing management for salinity control on nonsaline-slightly saline lands is to maintain only vegetation cover sufficient to minimize erosion and channel degradation while still allowing the greatest amount of runoff. This may require moderate or heavy grazing within a grazing management formula. Range condition should normally be maintained in no more than a good condition class. However, the resulting loss of water to the upland site may well cause a reduction in livestock and wildlife forage below optimum desired production.

2. Moderately Saline Lands

Management objectives on moderately saline lands should include the increase of ground cover, litter, and improvement in soil tilth necessary to increase infiltration and reduce saline runoff. Rangelands should be maintained in good to excellent condition. Grazing treatment should provide light or moderate utilization of forage as computed only on grazed pastures. The rest cycle should be long enough for soils to recover from the effects of trampling (compaction) through frost-heaving. This period varies with soil texture and in no case should be less than the time needed for seedling establishment.

3. Highly Saline Lands

The 1977 Salinity Status Report (3) suggested that removal of livestock from the highly saline lands could be an effective means of controlling salinity. These lands are often characterized by unstable soils and sparse vegetation. Soils may be fine-textured and relatively high in sodium. They are easily compacted by trampling under these conditions - resulting in low infiltration, high runoff, increased salinity, and low levels of effective soil moisture. It is felt that removal of livestock offers the greatest level of salt reduction in surface runoff on sites supporting a very sparse ground cover of perennial plants. On these sites, soil characteristics have a greater influence over infiltration than vegetation because of the large areas of bare ground and low percentage of litter. Frost-heaving or shrink-swell can change a hard packed soil into a fluffy, friable soil surface, greatly increasing infiltration. Grazing when soils are not frozen can adversely affect this friable soil condition.

On areas where ground cover of perennial plants is sufficient to support grazing animals, grazing should normally occur when soils are frozen (26). This use should allow sufficient rest from grazing at a time when the freeze-thaw cycle will improve soil tilth through frost-heaving. The grazing period reported on by Lusby (26), which encompasses the season when soils would be most likely to freeze, is November 15 through February 15. Figure 1 illustrates the effect of sheep grazing upon a loose, friable soil during the critical spring period when soils are moist and unfrozen (through March 31). Forage utilization should not exceed 50 percent on grazed pastures (11). If forage utilization is

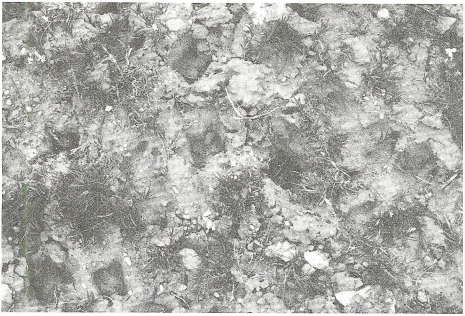


Figure 1. Deep hoofprints made by sheep grazing on a moist, unfrozen clay loam soil.

no more than 50 percent, a reserve of vegetal cover will be created for watershed protection and use by livestock during drought years. Grazing use should be rotated to rest plants from continuous winter defoliation.

Table 1 shows the result of two treatments on reducing salinity in surface runoff from highly saline lands in the Upper Basin States of Colorado, Utah, and Wyoming. The winter grazing treatment reflects a 10 percent decrease in the amount of salinity compared to the ungrazed condition (based on discussion with Gregg Lusby - 27). Salinity control through grazing management would cost over twice as much as that achieved by total removal of livestock. However, salinity control through grazing management still yields nearly two dollars in benefits for every one dollar spent. The reductions in livestock shown for winter grazing (grazing management) may, in many cases, be accomplished in connection with proposed adjustments in use as analyzed in grazing environmental impact statements (EIS), e.g., adjustments proposed in the Grand Junction Grazing EIS (4).

Table 1. Economic Impact of a Winter Grazing System and Livestock Removal on Salinity from Highly Saline Lands in the Upper Colorado River Basin.

	Benefits[1]				Costs			
Treatment Practice (3 million acres)	Sediment Reduced (tons/yr)	Salt Reduced (tons/yr)	Salt Concentration Change (mg/l/yr)	Total Annual Benefits[2]	Forage Reduced (AUMs/yr)	Water Retained On-Site (ac-ft/yr)	Total Annual Costs[3]	Salinity Cost-Effectiveness[4] ($/mg/l/yr)
Livestock Removal[5]	2,468,598	89,437	-6.86	4,594,000	95,024	12,206	985,000	143,600
Winter Grazing[6]	2,221,738	80,493	-6.21	4,150,000	20,500[7]	10,985	1,888,000	304,000

[1] Benefits are based on the following baseline data taken from BLM (3), Appendix XII-2, and (22), all indexed to 1979 dollars:

a) Value of a reduction of 1 mg/l at Imperial Dam = $425,000;
b) Value of keeping 1 ton of sediment out of Lake Powell = $0.68;
c) The buildup factor (present worth of one for a project life of 50 years) = 14.77.

[2] Total Annual Benefits is the sum of annual benefits from reduced sediment in Lake Powell and reduced salt concentrations in water measured at Imperial Dam. Based on data taken from Appendix XII-2 of BLM (3), pages 2-3.

[3] Total Annual Costs for the Livestock Removal Treatment Practice is the sum of annual costs associated with water lost to downstream users by keeping water on-site, BLM maintenance costs (exclusion fences, trespass control), the loss of grazing fees to BLM when grazing is reduced, and the loss of income to the rancher. Total Annual Costs for the Winter Grazing Treatment are the cost of grazing management including physical improvements (fences, watering facilities, roads, etc.), maintenance, and operation; and the cost of water kept on-site. Based on data taken from Appendix XII-2 of BLM (3), pages 2-4 and 5.

[4] See page 19 for a discussion of cost-effectiveness.

[5] Based on data taken from Table VII-2, BLM (3).

[6] Values for sediment and salt reduced in this Treatment Practice are computed as a 10 percent decrease over those computed for the livestock Removal Treatment Practice.

[7] Figure taken from Grazing Management value in Table VII-2, BLM (3).

V. RECENT GROUNDWATER INVESTIGATIONS

Recent investigations on the contribution of interflow to salinity of groundwater in arid and semiarid regions of western Colorado revealed that recharge does not come from precipitation falling on large areas of rangeland (31). Salinity profiles in the weathered materials suggested these soils were not an avenue for recharge. Evidence from both sites indicated that the direction of net water movement in soils was upward rather than downward. McWhorter and Skogerboe (31) theorized recharge occurred when runoff or snowmelt on the upper borders of the watershed intersected exposed bedrock. Data from a series of observation wells showed that groundwater moved along a contact between bedrock and the soil profile.

In a draft report, Warner and Heimes (41) discussed the findings of an extensive groundwater study in that part of the Upper Basin above the confluence of the Green and Colorado Rivers. This large region was divided into 9 subregions or basins. Data were collected on streamflow, conductivity, and water quality through chemical analyses. Measurements were taken in December and January when streamflow was at a low level, made up primarily by groundwater discharge. Cold temperatures at this time of year would have made surface runoff from melting snow very unlikely, and there was no observed rainfall. The volume of irrigation returnflow should also have been at a minimum. Measurements were not taken as a part of this study in areas where adequate data existed as a result of previous studies, as, for example, the Piceance Basin oil shale investigations.

The area covered by the Warner and Heimes report yields 74 percent of the water and 77 percent of the salt contributed by the Upper Basin. The measured groundwater contribution to the total annual salt load of this part of the Upper Basin was 55 percent. However, the groundwater contributed by each of the 9 subbasins varied considerably, from a low of 30 percent in the Upper Green River Basin, to a high of 93 percent in the Lower Colorado River Headwaters. In general, the percent of total salt load contributed by groundwater was higher for subbasins in the Colorado River Region, an average of 69 percent, than for subbasins in the Green River Region, an average of only 38 percent (41).

The Upper Colorado Headwaters subbasin is an area of high mountain country on the west slopes of the Continental Divide. The geologic formations are classed as slightly to nonsaline. The soils are Inceptisols, Alfisols, and Mollisols which are normally low in salts or have been leached by virtue of their location at higher elevations. Vegetation is alpine tundra, conifers, mountain shrub, and meadowlands (3). Salt concentrations in runoff would be very low (19). This subbasin produces 28 percent of the total water for the study region and only 16 percent of the total salt load. However, the subbasin accounts for 26 percent of the total salt contributed from groundwater. Of the salt produced by the subbasin, 87 percent comes from groundwater yielded by the Eagle Valley Evaporite Formation and from Glenwood and Dotsero Hot Springs (41). Point source salt contributions can be very significant. The Water and Power Resources Service (WPRS, formerly the Bureau of Reclamation - 5) estimates that 500,000 tons of salt, or nearly one half of the total subbasin salt load, are produced annually by the Glenwood and Dotsero Springs.

The effect of irrigation returnflow on the salt load from groundwater during the base flow period (winter) is very small for most subbasins, especially those at high elevations. Soils being irrigated are the alluvial, relatively well-drained deposits along streams. The distances groundwater (irrigation returnflow) must travel before entering a stream channel are, in most cases, relatively short. Therefore, water quality data collected in December or January should reflect a minimal influence from irrigated agriculture. However, the larger blocks of farmland located on fine-textured, poorly drained soils, and/or at long distances from streams can have a great influence on groundwater. Examples of these would be the Uinta and Price River Basins in Utah, the lower Gunnison and Grand Valley Projects in Colorado, and the Eden-Farson Project in Wyoming.

Water quality data were collected on drainage channels in the Lower Gunnison and Grand Valley areas thought to be yielding only irrigation returnflow. The annual salt loads from these channels were subtracted from salt loads estimated to be contributed by natural groundwater. All of the base flow salt load contributed by the Price River was believed to be from irrigation returnflow and was subtracted from the total. An average value of 50 percent of the base flow salt load was arbitrarily set for irrigation returnflow on the San Rafael, Duchesne, and Blacks Fork Rivers, and Piceance Creek. A value of 20 percent was similarly estimated for irrigation returnflow salt load from the Big Sandy River. These were all subtracted from computed total salt loads for the subbasins. Table 2 shows the results of this exercise.

It is estimated that the contribution of groundwater from natural sources to the total salt load of the Green and Colorado Rivers above their confluence is 38 percent. This is a reduction from the 55 percent measured as groundwater-contributed salt load (41). The remaining 17 percent of salt load would theoretically be from irrigation returnflow during the base flow period. This 38 percent from natural groundwater sources is in contrast to the 58 percent estimated by the Environmental Protection Agency to be from natural diffuse and point sources (16). The EPA also estimates that the total annual yield to the salt load from irrigation returnflow is 41 percent and 1 percent from industrial and municipal sources. BLM (3) estimated that surface runoff from the public lands yielded a total of 8 percent of the total salt load of the Upper Basin. Surface runoff from similar lands owned or administered by private individuals, states, Indian tribes, and other federal agencies probably yields an additional 7 percent of the Upper Basin salt load. These estimates account for 95 percent of the total salt load. The 5 percent unaccounted for is well within the error of these calculations.

Table 2. Estimated Values for Salt Load Contributed by Natural and Irrigation Returnflow Groundwater.*

Subbasin	Total Salt Load[1]	Measured Base Flow Salt Load[2]	Less Amount Estimated for Irrigation Returnflow	Total Natural Base Flow Salt Load
Upper Colorado River Headwaters	1,117,300	974,200	0	974,200
Gunnison River Basin	1,364,600	726,200	344,400	381,800
Lower Colorado River Headwaters	1,113,100	1,040,000	690,800	349,200
Dolores River Basin	489,800	282,500	0	282,500
Middle Upper Colorado River	-268,800	-384,700	0	-384,700
Upper Green River Basin	1,135,000	335,400	36,000	299,400
Yampa River Basin	411,700	161,100	0	161,100
White River Basin	275,100	195,700	8,000	187,700
Lower Green River Basin	1,213,300	466,100	129,700	336,400
Totals	6,851,100	3,796,500	1,208,900	2,587,600

* In tons per year.

[1] Taken from BLM 1977 Salinity Status Report (3).

[2] Taken from Warner and Heimes (41).

In summary, salt contributions from the Upper Basin can be outlined as follows:

Natural Groundwater (diffuse & point sources)	38%
Surface Runoff from Rangelands (BLM, private, & State)	15%
Surface Runoff from Forests & Error in Calculations	5%
Irrigation Returnflow	41%
Industrial & Municipal	1%
Total	100%

This exercise gives a gross accounting of sources of salt in the Upper Basin. It was done for the purpose of trying to better identify the contribution of natural sources, an area that has been ignored because of the difficulty in obtaining data. Hyatt et al. (19) states that only 20 percent of the 1931 to 1960 average annual salt load from the Upper Basin is traced to its area of origin through actual measurements. Therefore, most estimates of the natural salt load are derived by determining the salt load from agriculture, industry, municipalities, and natural point sources, then attributing the remaining salt to "other natural sources." It is believed that the estimates presented in this report give a more accurate value for the salt load contributed from natural diffuse sources.

VI. TECHNOLOGY OF CONTROLLING SALINITY IN GROUNDWATER

Saline groundwater can be manifest on the surface through a number of different kinds of discharge points. These have been studied to better understand mechanisms that affect flow of groundwater to the surface, a necessary step before it can be controlled. Some important point source emissions of groundwater are listed below with an explanation of possible factors affecting their surface discharge.

Flowing well, borehole	--	Man-caused saline groundwater discharge by artesian pressure.
Artesian spring	--	Natural discharge of saline groundwater under pressure.
Spring, seep	--	Point source saline discharge by gravity along a fault or outcrop of porous material.
Effluent stream or groundwater interface	--	Gravity discharge of saline groundwater along a fault or porous material ending in a streambed. This may be either a point or diffuse source emission.

A. Springs and Seeps

Saline springs and seeps allow examination of saline aquifers through a surface discharge. Such discharge points are easier to locate and may be easier to control than more diffuse inflow directly into channels. Possible control measures are evaporation ponds, deep well injection, and plugging. Evaporation requires a means of collecting all discharge, a conveyance system, and a suitable disposal site.

A collector system may consist of a concrete or earthen dike with its base anchored to an impervious layer (bedrock, tight clay), located downslope of the spring. A dike can be relatively short in length when a spring discharges from one point or may be long when discharge is emitted from several scattered points or a diffuse area, as in the case of a seep. The major concern in designing the dike is that it should completely intercept saline waters, thus preventing salt from entering perennial streamflow and/or storm runoff. Care should be taken to minimize the inflow of overland storm runoff into the collector. A large volume of runoff water entering the system could cause saline spills or rupture of the collector dike. Saline water is collected behind the dike into a pond or sump where it can be diverted into a conveyance system. Dikes can also be placed across a channel to intersect and divert subsurface channel flow.

The conveyance system transports saline water from the source (collector) to the disposal site. It can take the form of an open channel (ditch) or a closed pipeline. A lined, open channel can function well where it can be designed for gravity flow and intersecting drainage channels can be crossed without difficulty. Chances for failure of the system are reduced and greater protection is afforded to the surrounding environment with a closed pipeline. If the disposal site is located at an elevation higher than the collector, a pump and pipeline are required.

The disposal site should be located as close as possible to the salt source. Evaporation ponds are a possible means of disposal if a relatively level plot of land of sufficient size is available nearby. An evaporation pond system should have a storage capacity sufficient to hold the annual saline spring discharge, plus annual precipitation (rain or snow), plus volume of accumulating salt over the life of the project, and less the annual amount of water lost through evaporation. A series of evaporation ponds is desirable if sufficient level ground is available. Accumulated salts from evaporation will be concentrated in the last pond of the series. The other ponds would have decreasing salt concentrations, progressing from the last pond back toward the source, with the first pond having a salinity only slightly greater than the saline source. The first ponds in the chain could potentially provide habitat for waterfowl. The ponds with the highest salt concentrations could be hazardous to waterfowl.

Dikes creating evaporation ponds should be high enough to afford protection against overflow resulting from wave action and should provide storage of abnormally high amounts of precipitation. The dike system should also keep overland storm runoff from entering the evaporation ponds. Cost of pond construction will be less when ponds are located on fine-textured soils. The bottom and sides of ponds must be sealed to eliminate seepage. Materials suitable for lining ponds are fine-textured soil (clay), bentonite, and man-made products (polyvinyl chloride-PVC or hypalon). The size of ponds may be reduced by the installation of an aeration system (sprinklers). However, this requires a power source, greater maintenance, and increased operation costs. Preliminary studies by WPRS indicate that evaporation rates are highly variable and are significantly reduced as concentration of salts approach brine conditions. This could affect the size of ponds needed or even the viability of the use of evaporation ponds for salinity control.

The deep well injection disposal process is only possible where geologic formations are porous enough to accept brine and yet not so fractured that brine would escape to contaminate freshwater aquifers. This process is currently being used by oil companies as a means of disposing of saline water, a byproduct of oil production. However, deep well injection is a costly process. It requires an adequate supply of power to pump brine under pressures sometimes reaching 3,000 pounds per square inch (psi). It may also result in damaging environmental side effects if brines leak into freshwater aquifers or pressure-caused earthquakes occur.

B. Flowing Wells

Abandoned oil and gas exploration wells may penetrate a number of freshwater and saline aquifers, some at several thousand feet below the surface. If these are under artesian pressure, water mixing can occur between aquifers, causing contamination of freshwater. Artesian pressures can also force saline water to the surface, discharging over the land, with a potential for contaminating surface streams. Water from deep formations can be extremely saline, with concentration of salts of 10,000 or more milligrams per liter (mg/l). Surface contamination from saline aquifers can be eliminated by plugging above and below the water-producing geologic formation. If the well cannot be successfully plugged, the saline water can be collected on the surface and disposed of in an evaporation pond.

Before attempting to plug an abandoned oil well flowing under artesian pressure, it should be recognized that a number of potential problems can be encountered. A successful operation depends upon a knowledge of the stratigraphic column (position and order of sequence of geologic strata) from the bottom of the well to the surface. This would include information on lithology (structure, mineral composition, color and texture of rock formations), porosity, and permeability. The depths and intervals of aquifers must be known, as well as the identification of those under a hydraulic head (artesian). The date the well was drilled and cased, the type of casing used (including diameter and material), total depth of casing, and depth and interval of perforations or screens must be known. Such information can be obtained from a detailed driller's log (9). An analysis of chemical constituents in the water (corrosive properties) will give a clue to the present condition of the casing (6).

The structure and mineral composition of rock units will affect whether the walls of the hole are stable or may have caved in or will cave in during plugging operations. Cement plugs may not effectively seal off aquifers if the casing has rotted away or if the hole walls are not stable. If the condition of the well is very poor, a new hole may need to be drilled alongside it. This can greatly increase costs. Drilling out an existing cased hole can be expensive if rotted casing, sloughing of the hole walls, or other detrimental conditions cause equipment to be lost in the hole during drilling. Problems can also occur if grouting is not used or is improperly done, allowing saline water under artesian pressure to flow around the casing or outside the well bore via fractures and reach the surface or contaminate other aquifers. The Ground Water Manual (6) gives a good explanation of how a cement-based grout between the soil walls of the bore and the casing cannot only seal a well but can also serve as a concrete casing if the steel casing is lost through corrosion.

VII. CONTROL OF SALINE POINT SOURCE GROUNDWATER DISCHARGES

A. Determining Technical Feasibility

The proper design of a facility for controlling point source saline groundwater discharges requires data collection about the origin of the groundwater, how and where it discharges, the water itself, and terrain of the surrounding area. First, a reconnaissance level investigation should be made to determine if more detailed studies are warranted. Measurements should be taken to determine the rate of waterflow, any variation in quantity of flow, and electrical conductivity (concentration of total dissolved solids [TDS]). The area surrounding the discharge point should be inspected to see if a tract of flat land exists large enough for an evaporation pond. Soil texture on the proposed site should be noted. Apparent depth of soil and existence of rock outcrops should also be noted.

If reconnaissance investigations indicate a control project may be feasible, more detailed studies can be made. This would entail gathering additional information for the items discussed above.

B. Determining Economic Feasibility

Public Law 92-500, Clean Water Act of 1972, states that salinity standards must be met. This should be done in the most economic manner technically feasible.

An economic analysis should include an accurate determination of the project cost-effectiveness as well as local and downstream economic benefits. Cost-effectiveness relates the total annual cost of a project to the expected reduction in salt concentration as measured at Imperial Dam, California. Cost-effectiveness is an efficient yardstick to measure and compare salinity control projects having equivalent downstream benefits and can be applied to other agency programs and basinwide efforts as well. Economic benefits are generally described in terms of an incremental economic detrimental value related to salt concentration changes at Imperial Dam. The economic detriment (or benefit) at Imperial Dam is a composite value representing annual damages to downstream municipal, industrial, and agricultural users in the United States. This study uses an economic detriment value of $425,000 per mg/l per year based on $343,000 per mg/l per year (22) and indexed to 1979 dollars.

The computed reduction in salinity, as a result of each project, is the annual sum of the positive effects of removing a given number of tons of salt and the negative effects of detaining a given number of acre-feet (ac-ft) of water. The removal of salt reduces the salt load, while the loss of water raises the TDS concentration. The net effect will be a lowering of the concentration if the amount of salt lost is high in relation to the amount of water detained. Reductions in salt concentrations at Imperial Dam resulting from each project were computed using data from Table E (7).

The following sections illustrate the kinds of preliminary investigations that should be completed before a project is recommended for funding and an engineering design made. Sections C.1. and C.2. illustrate two technically feasible projects to control saline springs - the first is clearly economically feasible, the second is not clear. Section C.3. illustrates a successful well plugging.

C. Case Studies

1. Diffuse Point Discharge (Salt Creek) Spring

Salt Creek drains Sinbad Valley and is tributary to the Dolores River. The mouth of Salt Creek is located nine miles southeast of Gateway, Colorado. Base flow is furnished by several small springs at or near the mouth of Sinbad Valley. High flow comes from snowmelt and rainfall runoff. Surface flow in Salt Creek is ephemeral, drying up in the hot summer months; subsurface flow is perennial. Discharge from the saline springs at the mouth of Sinbad Valley is perennial, yielding approximately 100 gallons of water per minute (gpm) or 160 ac-ft per year. Concentration of salts in this water is 61,200 mg/l, resulting in a total salt yield of 13,317 tons annually. If the flow from these springs could be kept from entering the Dolores River, this action would result in a reduction of salt concentrations of 1.11 mg/l at Imperial Dam.

A reconnaissance of Sinbad Valley was made to locate a suitable site for evaporation ponds. A fairly large area of relatively flat ground was found on private land just south of the proposed collection site. Figure 2 shows one proposal for location of facilities needed to control salt using evaporation ponds. This procedure would require a collector made up of a barrier dam, a sump, and a pumping plant. The collected water would be pumped up-slope a short distance through a pipeline and evaporated in four ponds. This site would reduce the length of the pipeline to a minimum.

The cost-effectiveness and benefits are computed using the following information:

Detailed Cost Analysis

Assume:

$425,000 = Cost of 1 mg/l rise in salinity at Imperial Dam (economic detriment value).

1.11 mg/l = Benefit from the salinity control system.

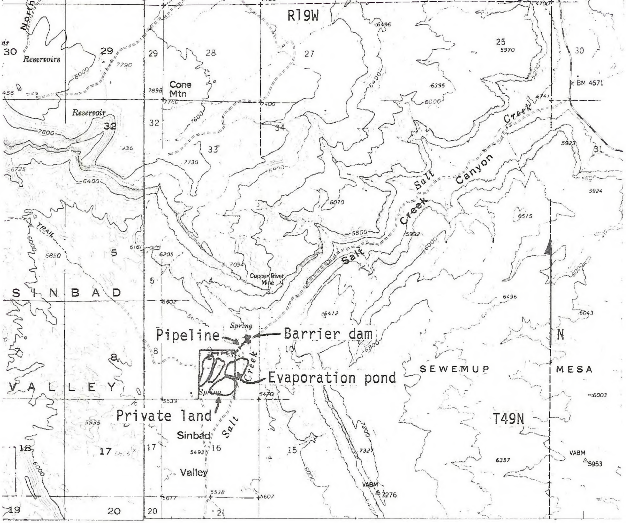


Figure 2. Proposed salinity control facilities for Salt Creek, southwestern Colorado.

a. Construction/Development and Replacement Costs

(1) Collector system

Barrier dam	$ 20,000
Sump (gravel pack and perforated drainpipe)	$ 10,000
Pumping plant	$ 10,000
Amount to be set aside for periodic replacement of pump (assumes replacement at 5-year intervals) $10,000 X 2.44 (Sinking Fund Factor)	$ 24,400
High pressure, 4 inch, rigid PVC pipeline, 0.6 mile @ $60,000/mile	$ 36,000
Amount to be set aside for periodic replacement of pipeline (assume a 25-year life), $36,000 X 0.22 (Sinking Fund Factor)	$ 7,920

(2) Evaporation pond (4 each)

Protective dike - includes cost to move earth from inside pond area to dike site, wet compaction and grade of dike fill material, and line inside face of dike with hypalon; see Day (15) for specific guidelines.

20 ft. high (32 cu. yd./ft) @ $48/running foot, plus hypalon liner (30 mil) on inside face of dike @ $20/running foot, 9,953 running feet of dike	$ 676,804
6 ft. high (4 cu. yd/ft) @ $6/running foot, plus hypalon liner @ $6.40/ running foot, 5,359 running feet of dike	$ 66,452

Pond liner of 20 mil polyvinyl chloride (PVC) material (not buried), 80 acres or 387,200 sq. yds.

Cost to prepare pond bottom (grade site flat and smooth, remove rocks), $.75/sq. yd. x 387,200	$ 290,400
Cost to purchase and install liner, $2.00/sq. yd. x 387,200	$ 744,400

(3) Power Line

Construct 4.5 miles of single phase power line to pumping site @ $10,000/mile.	$ 45,000
Two-phase converter	$ 1,600

(4) Land

Estimated cost of proposed purchase of 120 acres of private land @ $600/acre.	$ 72,000

(5) Management

BLM Engineering and Design Costs.	$ 140,000
Land Appraisal.	$ 10,000
Preparation of Environmental Statement.	$ 328,000
BLM supervision of construction	$ 18,000

b. Annual Recurring Costs (Operation and Maintenance)

Electric power (53,243 KWH/year)	$ 2,460
Repair of pond dikes (including material).	$ 10,000
Overhead and maintenance personnel costs	$ 12,000

c. Cost-Effectiveness and Benefit Analysis

Total Annual Costs . . . . $ 253,629

Cost-Effectiveness:

$$\frac{\$\ 253{,}629 \text{ per year}}{1.11 \text{ mg/l reduction}} = \$\ 228{,}494 \text{ per mg/l per year}$$

Incremental Economic Benefits. . . . . . $ 425,000 per mg/l per year

Total Annual Benefits:

$ 425,000 x 1.11 mg/l = $ 471,750

Alternative ways of reducing salinity were examined to identify which alternative would yield the greatest effectiveness (i.e., mg/l of salt per dollar cost) versus the cost of reduction. The cost-effectiveness of this project is most favorable when compared with the incremental economic benefits of the other alternatives.

2. Point Source - Stinking Spring (Onion Creek)

Onion Creek drains Fisher Valley and is tributary to the Colorado River. The mouth of the creek is located 19 miles northeast of Moab, Utah. Base flow originates in the La Sal Mountains and is used for irrigation of hay fields in Fisher Valley. Base flow is approximately 2 cubic feet per second (cfs) and salt concentration is 800 mg/l as the creek enters the "narrows" of Onion Creek Canyon. Stinking Spring discharges approximately 80 gpm into the creek from two major points; one yields 57 gpm at a concentration of 18,980 mg/l, the other discharges 23 gpm at a concentration of 14,600 mg/l. These two combine to yield a total of 128 ac-ft of water and 3,084 tons of salt annually. Salinity of Onion Creek below Stinking Spring increases to 3,100 mg/l. If Stinking Spring water could be kept from entering the Colorado River, the salt concentration at Imperial Dam would be reduced by 0.24 mg/l.

Figure 3 shows the possible location of a control structure and collector which would prevent saline spring water from entering Onion Creek and divert it into a pipeline. It also shows the pipeline location and the evaporation pond site. The pond would need to be lined to prevent brine seepage through sandy soil into the Colorado River. Day (15) provides a good manual on procedures to be followed in constructing brine ponds and installing liners to reduce seepage. The cost-effectiveness and benefits of the proposed project are computed as follows:

a. Construction/Development and Replacement Costs

(1) Collector System

Barrier dam and gravel sump	$ 20,000
3-inch, rigid PVC pipeline, 5 miles @ $60,000/mile	$ 300,000
Air release valves	$ 10,000
Amount set aside for periodic replacement of pipeline (assume a 25-year life) $310,000 x 0.22 (Sinking Fund Factor)	$ 68,200

(2) Evaporation Pond

Protective dike 20 feet high and hypalon liner on inside face of dike, 3194 running feet of dike @ $68/ft	$ 217,192
Protective dike 6 feet high and hypalon liner on inside face of dike, 2614 running feet of dike @ $12.40/ft.	$ 32,414
Pond liner of 20 mil PVC material (not covered), 64 acres or 309,760 sq. yds.	

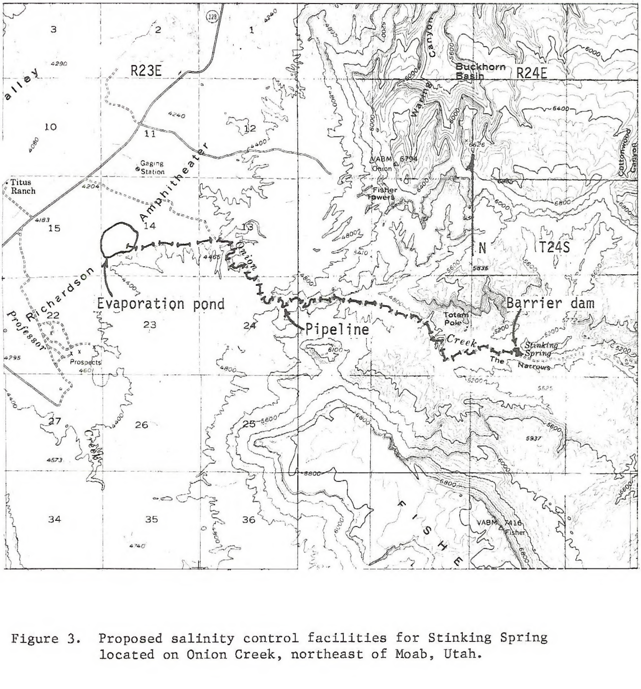


Figure 3. Proposed salinity control facilities for Stinking Spring located on Onion Creek, northeast of Moab, Utah.

Cost to prepare pond bottom (grade site flat and smooth, remove rocks) $.75/sq. yd. x 309,760	$ 232,320
Cost to purchase and install liner $2.00/sq. yd. x 309,760	$ 619,520

(3) Management

BLM engineering and design costs	$ 215,000
Preparation of environmental statement	$ 500,000
BLM supervision of construction	$ 20,000

b. Annual Recurring Costs (Operation and Maintenance)

Repair of pond dikes (including material)	$ 5,000
Overhead and maintenance personnel costs	$ 8,000

c. Cost-Effectiveness and Benefit Analysis

Total Annual Costs . . . . $ 212,500

Cost-Effectiveness:

$$\frac{\$\ 212{,}500 \text{ per year}}{0.24 \text{ mg/l reduction}} = \$\ 885{,}417 \text{ per mg/l per year}$$

Incremental Economic Benefits. . . . . . $ 425,000 per mg/l per year

Total Annual Benefits:

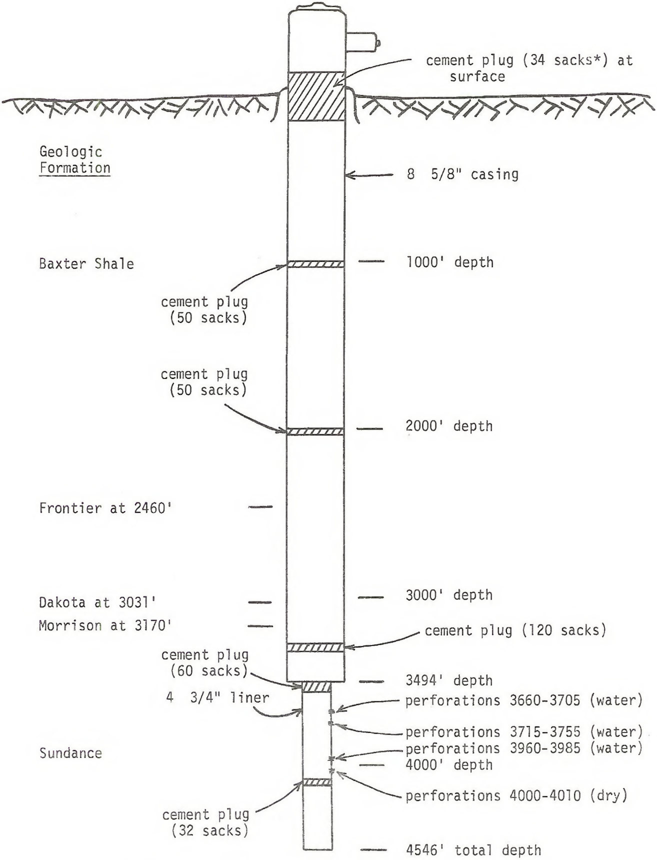
$ 425,000 x 0.24 mg/l = $ 102,000

This proposed project may be the most economical means of reducing salt concentrations in Onion Creek, in comparison with other potentially more expensive control practices such as deep well injection or reverse osmosis desalting treatment units.

3. Flowing Well

An exploratory oil well was drilled along Bitter Creek, just east of Rock Springs, Wyoming, in 1937. The well is located in the SW1/4SW1/4 of section 18, T. 19 N., R. 103 W., 6th Principal Meridian. It was drilled to a depth of 4,546 feet below ground surface. The hole was apparently cased to a depth of 3,494 feet, with a smaller steel liner extended to the 4,546-foot level. The liner was perforated at several depths (see Figure 4). A saline water-bearing zone under artesian pressure is located in the Sundance Formation. The well originally discharged about 700 gpm, but it was estimated to be releasing only 50 gpm in the summer of 1978 (see Figure 5). In 1978 TDS concentration was measured at 9,600 mg/l.

Figure 4. Available information about well, its development and plugging.



*Note: One sack = 1.1 cubic feet

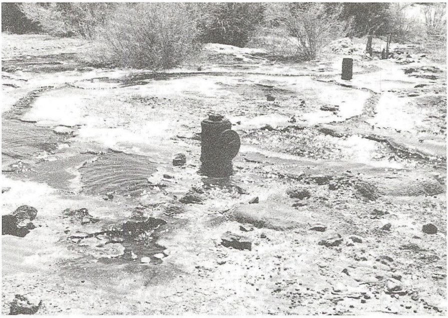


Figure 5. Area around the wellhead showing flow and accumulated deposits, June 1978.

The well was closed successfully with a cement plug at a depth of 3,474 feet in 1939. In 1963, it was reopened and the water used in the construction of Interstate Highway 80. Sometime thereafter, it was again plugged by pumping cement from the surface downward into the casing to a depth of 1,036 feet. The saline flow was stopped for a time, until the casing rotted away and water began flowing around the cement plug onto the surface at a rate of 50 gpm.

On September 22, 1978, preparations were begun to clean out the well and plug it a third time. A five-inch diameter hole was drilled through the 1,036-foot cement plug. An expandable packing device was positioned at 4,119 feet and mud pumped into the entire well column, stopping the waterflow. A series of six cement plugs were set in the well at varying depths to create a permanent barrier (see Figure 4).

The costs to plug the well in 1978 were as follows:

BLM supervision	$ 2,600
BLM and contract site preparation (gravel access road, level drill site, clean-up site)	$ 4,700
Drilling and plugging contract	$ 35,400
Total	$ 42,700

A flow of water at 50 gpm, with a concentration of 9,600 mg/l, would yield a total of 1,044 tons of salt and 80 ac-ft of water annually. Plugging of the well, totally stopping the saline flow, resulted in a salinity reduction at Imperial Dam of 0.073 mg/l. The annual value of this benefit would be $25,039. The cost-effectiveness and benefits are computed as follows:

Total Annual Costs (annualized on a 50-year basis) . . . . $ 3,774

Cost-Effectiveness:

$$\frac{\$\ 3{,}774 \text{ per year}}{0.073 \text{ mg/l reduction}} = \$\ 51{,}699 \text{ per mg/l per year}$$

Incremental Economic Benefits. . . . . $ 425,000 per mg/l per year

Total Annual Benefits:

$$\$\ 425{,}000 \times 0.073 \text{ mg/l} = \$\ 31{,}025$$

The cautions outlined in section VI.B. should be exercised when attempting to plug saline-flowing wells. Costs can greatly exceed those of the Bitter Creek Well Project; however, plugging of saline-flowing wells may be more cost-effective than evaporation ponds.

VIII. Future Studies

The conclusions in this and the 1977 Salinity Status Report regarding effects of man's activities on salinity have been drawn primarily from published results dealing mainly with effects on infiltration, runoff, and sedimentation. Recent results (studies funded by BLM and U.S.D.I., Office of Water Research and Technology) have shown a relationship between increased salinity and increased runoff and soil loss. These data were used as a justification for this extrapolation. However, the duration of the studies was short, 3 years at the maximum. Further studies relating to the effects on salinity levels of control of oil-gas activities, mining, ORV, and grazing are needed. Additional data are also needed on the feasibility of controlling natural and man-caused point sources of salinity from groundwater.

The following studies are suggested for future consideration in order to better understand the factors influencing salinity and the best means of reducing salt yields from public lands.

A. Research on the effects of grazing on hydrologic responses, and ultimately on salinity, should be continued.

As contrasted with previous studies, the main feature of this project would be the direct measurement of salinity as affected by grazing treatments. Data on other more conventional parameters, such as runoff, sedimentation, changes in vegetation, erosion, and infiltration properties, would also be collected. These data would improve our knowledge of the relationships between hydrologic responses and salinity.

B. A demonstration and experimental evaporation pond salinity control project could be constructed.

Salt Creek in western Colorado is a likely candidate for a site. Such a project would be studied to provide BLM with data on design problems, construction techniques and costs, maintenance problems and costs, evaporation rates, and effects on wildlife and other aspects of the environment.

C. Water quality data are necessary for preparing and monitoring success of land use and activity plans (i.e., allotment management plans).

In response to this and other resources' needs for information, a series of stream-gaging stations have been located in Colorado and Utah on ephemeral and perennial channels. These gages are providing valuable data on salinity levels from arid and semiarid public rangelands. The stations are located in regions where little data on water quality have been previously collected. Maintenance and operation of these stations should be continued. In addition, biological data should be collected on the watersheds above the gaging stations. These would provide information on factors relating to levels of salinity monitored by the gages.

Grazing treatments could be instituted on several watersheds or new gages installed on watersheds with existing grazing systems. New gaging stations are also needed in areas not presently included in the BLM salinity monitoring network, such as areas in northeastern Utah and Wyoming.

IX. SUMMARY

A. Salt From Surface Runoff

A number of activities, including livestock grazing, off-road vehicle use, oil and gas activity, mining claim exploration and development, and coal mining activity, can be contributing factors to salt in surface runoff from public lands. Each of these factors must be dealt with on a site-specific basis to determine the extent of salt contribution and to plan measures necessary to reduce the concentration to acceptable levels.

Improper livestock grazing can have a significant influence on the amount of sediment and salt yielded in surface runoff from rangelands. The importance of controlling the period and intensity of grazing, the kind of animal, and the need for rest from grazing to improve range condition is stressed. Light to moderate grazing during the season when plants or soils are least likely to be damaged, periodic rest from grazing through the use of grazing management systems, and total removal of livestock from areas with unstable soils or little potential to support a protective cover of vegetation are specific ways livestock can be managed to reduce salinity.

Salinity control through grazing management will vary with the concentration of salts in the soil. Specific management which may be employed for each type is as follows:

1. Nonsaline - Slightly Saline Lands

Grazing management to meet salinity objectives should strive to produce a maximum volume of runoff while at the same time maintaining a stable soil with a minimum loss of sediment through erosion. This loss of water to the soil-water reservoir will reduce forage production for livestock and wildlife below its natural potential. However, the higher quality water (usually below 300 mg/l salt concentration) will dilute the more saline waters in the Colorado River system and at Imperial Dam, California, and thus reduce salinity.

2. Moderately Saline Lands

Grazing of livestock at a light to moderate level, in accordance with a schedule of use and rest treatments designed to provide maximum protection for soil and plants, will reduce salinity in surface runoff. The objective on these lands is to increase infiltration and reduce runoff and loss of saline sediment. Salt concentration in runoff water exceeds that measured in receiving streams.

3. Highly Saline Lands

Moderate grazing in winter when soils are frozen may not significantly increase salinity on areas where forage production is sufficient to support grazing animals. Soil factors have a most important influence on infiltration and runoff on areas having a very sparse ground cover of perennial vegetation. Plants have only a slight influence due to their scarcity.

B. Prospects for Control of Salt from Point Source Discharge of Groundwater

Control of salt yielded from point sources can be technically and economically feasible. The Bitter Creek Well near Rock Springs, Wyoming, was successfully plugged for a very favorable cost-effectiveness of $51,699 per mg/l per year; the economic detriment value was $425,000 per mg/l per year. However, it should be pointed out that the financial and environmental risks involved in dealing with aquifers located at great depths and/or aquifers under pressure can be significant.

The proposed control of salt in Salt Creek, Colorado, using a system of lined evaporation ponds appears to be technically and economically feasible, with a cost-effectiveness of $228,494 per mg/l per year. This is due to the extremely high salt concentrations in the water.

A similar project on Onion Creek, Utah, has a poor cost-effectiveness of $885,417 per mg/l per year because of the lower concentration of salts in Stinking Spring. It is, however, still technically feasible. If the decision were made that salinity control is desirable at the site, a cost-effectiveness comparative analysis could be made with other units to determine the least costly alternative. Under such a procedure, the evaporation pond may still prove to be the most economical treatment.

X. ERRATA TO 1977 SALINITY STATUS REPORT

Appendix XII-1 of the 1977 Salinity Status Report (2) discusses the elimination from grazing of areas that are unsuitable for that purpose. These areas usually are too steep or rocky, lack sufficient forage, or are covered with dense trees. In the Soldier Creek allotment example, 60 percent of the juniper-pinyon vegetative type was listed as being usable. The grazing capacity was eliminated from the other 40 percent, leaving use on 6,907 of the 11,512 acres. In computing the results of grazing management or removal of livestock as treatments for controlling salinity, no benefits should have been credited to the unused acreage. However, this reduction was not made, resulting in too high estimates of benefits from the two grazing treatments.

Although the error made on the Soldier Creek allotment is significant (11 percent), when it is combined with the other two sample allotments and extrapolated to all highly saline lands in the Upper Basin, the overall error is a nonsignificant 1 percent. Therefore, the data on benefits in the 1977 Salinity Status Report will not be changed. When computing salinity benefits, care should be taken to remember to deduct effects on unusable areas.

The table on the top of page 1-11 of Appendix XII-1 is incorrect as presently shown. It should read as follows:

Vegetative Type	Acreage	Grazing Capacity Ac/AUM	Usable AUMs
juniper-pinyon	6,907*	40	173
big sagebrush	3,547	20	177
black sagebrush	3,432	15	229
shadscale & greasewood	4,629	50	92
			671

*Note: Total 11,512 acres of juniper-pinyon, of which 6,907 acres or 60% are usable by livestock.

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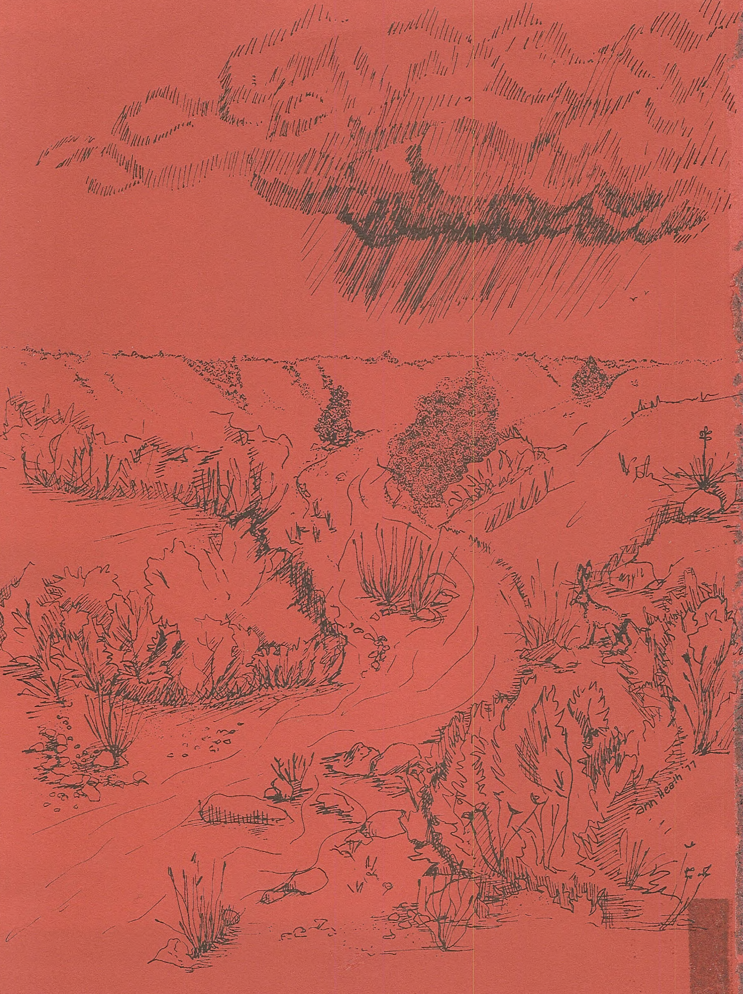
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